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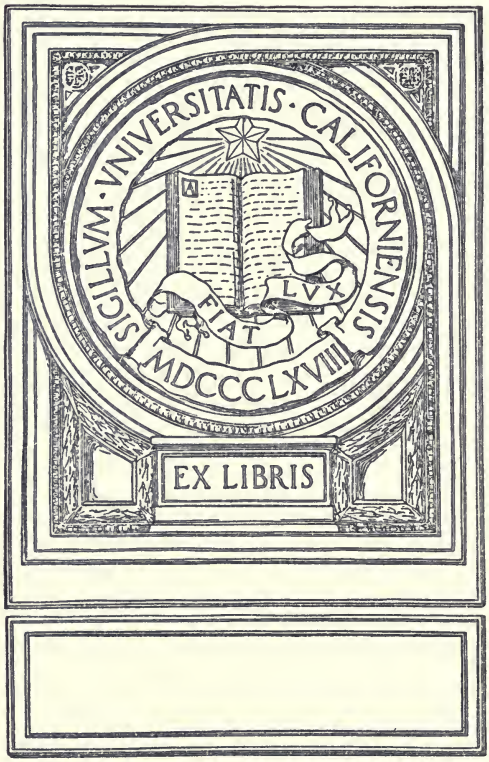

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MEMOIR OF
HAYWARD AUGUSTUS HARVEY

W. A. Harvey

C Harvey, Thomas Williams

MEMOIR OF HAYWARD AUGUSTUS HARVEY

BY

HIS SONS

Faites ce que l'honneur exige

WITH PORTRAITS AND ILLUSTRATIONS

NEW YORK
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In writing this memoir of our father we have received valued assistance from many of his personal and business friends, and to them we wish to express our sense of gratitude. Particularly are we indebted to Mr. Frederic H. Betts, Counsel; Mr. Edwin Marshall Fox, European Agent; Mr. Joseph H. Dickinson, Superintendent; and the late William Allen Smith, Secretary of the Harvey Steel Company; also to Mr. Cornelius Winant and to Mr. James C. Bayles.

We also wish to express our appreciation of the loyalty to the memory and fame of our father, shown by all of those who have been connected with the steel company in any capacity.

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MEMOIR OF HAYWARD AUGUSTUS HARVEY

This loving tribute to the memory of Hayward Augustus Harvey does not claim to rank as a biography, and can but sketch in outline the varied and useful activities which made up his life-work. A history of his life would be, in some sense, the history of a generation of progress in the mechanic arts. His versatile genius, though mainly directed to certain definite ends, in the pursuit of which he admittedly led the world's development, found profitable fields of activity in so many directions that one who would seek to follow his footsteps would be bewildered by their many deviations from what seemed to be the path of his greatest usefulness. All that is attempted in this monograph is to present a few memorable facts of his life-work in approximate chronological order, in the assurance that they will be of interest to

his many friends, and perhaps useful to the future historian of the wonderful progress in the arts and sciences which has made the last quarter of the nineteenth century memorable, whatever the future may have in store for coming generations of men.

However incompletely or imperfectly told, the story of the life of one whose genius has revolutionized more than one industry will be read with interest. To those nearest to him by the sacred ties of kindred, his lovable personality, and the charm of his exalted character as husband, father, and friend, obscure and render impossible of just and critical estimate his genius as a mechanic and his influence in the industrial development of his time. We loved him too well, and were too close to him to realize how great a man he was in his work.

Hayward A. Harvey was a striking example of the heredity of genius. His father, General Thomas W. Harvey, was one of the most remarkable men of the first half of the nineteenth century. He was a pioneer in mechanical invention and in the application of original devices

in automatic machinery. One who attempts to follow his work soon discovers that the father was embarrassed by the number and wide variety of the matters claiming his attention. For the son fewer "original vacancies" in the mechanic arts existed. He was able to focalize his work with somewhat sharper definition, though not as completely as the specialist of the present day is able to do.

His training in the specialties, to which he had devoted himself throughout his life, had been from the beginning eminently practical.

He had little use for theoretical reasoning or professional formulæ. He could not have been called scientifically educated, as he had not had access to the science of the schools until his later years. He, like his father, was a pioneer who, with keen and ready axe, blazed the path for those who would follow; while in their specialties both gave to the world, as the result of their experiments, many completed works, in other and neighboring fields they made many experiments, which, stopping short of practical results at that time, were distinctly prophetic; as instances we may cite the use of electricity as a motor power, the

magnetic separation of iron ore, and the production of steel direct from the ore by one process, all of which both father and son helped to make practical by original experimentation.

Mr. Harvey's method of approaching a mechanical problem is indicated by the following anecdote:

He asked one of his sons, "How would you go to work to invent a machine for accomplishing certain results?" The answer was, "I would look up what had been done by others, in encyclopædias and other authorities, obtaining as thorough a knowledge as possible of the art." "If I should begin in that way," Mr. Harvey said, "I would never make an invention. I would never get out of the beaten track. No, I would solve the problem in my own way first, and then find out what others had done in the same field; and it has usually turned out that I have solved the problem by an entirely original and usually a simpler method."

He possessed, to a remarkable degree, the characteristic questioning mind of the American inventor. A machine in motion not only

explained itself to him quickly, but immediately suggested other and generally simpler ways of accomplishing the same result. The following incident illustrates this trait very forcibly. He had invented and built a machine for making nuts for bolts. It was a complicated piece of automatic machinery, and had taken many weeks to perfect. After his return from the town where it was building he was asked as to his success. He answered, "I have had one of the great disappointments of my life. I did not see that machine in action but a moment when there flashed into my mind the plan of a machine which would do the same work with about half the complications of the present one."

In his relations with his fellow-man he was simple, straightforward, and supremely honest. Everyone who had business dealings with him of whatever character always trusted him implicitly and with safety. He was always hopeful, but without the exaggerated expectations common to inventors. Having become convinced of the soundness of his speculations and calculations, he was so certain of the ultimate success of their practical application that

he would not entertain a suggestion of their failure, and it was a very unusual event when time did not demonstrate the firm foundation on which he had based his hopes.

He made few inventions in any field of mechanics which did not remain as important factors in the development of the art. To him this was more important than any pecuniary reward that he might derive from them. He not only was preëminent as an inventor, but he was always successful in interesting capital in his enterprises, both on account of the originality and value of his inventions, and also because he had always a carefully drawn up and convincing scheme of organization for the new industry which commended itself very quickly to those whom he was striving to interest. He was thoroughly familiar with the business side of the fields of industry in which he was interested. From boyhood he had been drawing, designing, and building automatic machinery, and from his earliest days he had been experimenting in the metallurgy of iron and steel. His mind was stored with the results of years of thought and practical work in these fields, so that when it came to the problem of or-

ganizing a screw-manufacturing plant or a steel company, his was the master mind that worked out and arranged the plan of organization, formulated the items of outgo and income, and demonstrated the ability of the new concern to make a profit.

A very striking characteristic was his consideration for others. This was shown not only by kindly acts in his family and by courtesy toward his friends and acquaintances, but in all his business relations, wherein he was always regardful of the rights of others, even his opponents. In the competition of business, as in the home circle, he ever displayed the qualities which characterize the Christian gentleman.

A high tribute to his business probity was paid by Mr. Edwin G. Angell, President of the American Screw Company, in a letter written to Mr. Harvey on June 27, 1889.

For over thirty years there had been a very intimate business relationship between these two men of a most varied character. At times they would both be together on the same side of a business transaction, again they would be opposing each other, their personal relations always remaining most cordial.

Mr. Angell in this letter says, "Nothing has ever impressed us, in our intercourse with you, more than your general spirit of fair dealing."

A further development of this side of his character was his generosity. Whenever fortune had favored him his first thought was for those who were needy. The question of a profitable investment was not entertained until he had satisfied himself that he had relieved to some extent the necessities of others, and this, too, in the scriptural manner, the members of his family seldom knowing the extent of his charities.

As it is impossible to separate entirely his work from that of his father, General Thomas William Harvey, we have included a short account of the life and activities of the latter, a study of which shows clearly the source from which the son drew his genius and habits of thought.

General Harvey was a country lad trained at the village forge, who having spent fifteen years of his early manhood in a frontier town, came east in 1832 with an invention, which was the mother of all the machines in which a head is upset on a blank, and its influence is still felt

wherever a die is used or a bolt, screw, nail, or pin is headed. He followed this up with the gimlet-pointed screw and the machinery for making it. Prior to his inventions, there had been a few attempts to cut the threads and nicks of screws by machinery, but most of the screws were made laboriously on a lathe or a "screw-cutting gauge." All the steps were taken separately and by hand.

His inventions of 1846, wherein he devised a complete system of automatic screw machinery, contained the basic principles of all the screw inventions for the succeeding thirty years. He is known and recognized by the world as the original inventor of the gimlet-pointed screw.

His son left behind him as the special monument to his memory the harveyed armor plate, in connection with which his fame and name have spread throughout the world.

A perusal of these pages will show, however, that he has accomplished great things also along the lines in which his father had labored, and his machine for rolling the threads of screws, first by means of rolls, and afterward by the reciprocating dies, or cold forging as it is called, was an original and epoch-making invention,

and one which has caused an entire change in the screw machinery of to-day, on both sides of the ocean.

LINEAGE

The founder of the family in America was William Harvey, one of the earliest immigrants to the Massachusetts Bay Colony. Soon after his arrival in this country he, with sixteen others, founded the town of Taunton, which was named, so says tradition, from the town in England, whence these people had come. Tradition further has it that the great-grandfather of William was a certain Turner Harvey, a noted archer of the time of Henry VIII. (about 1525). He was said to have been in his time the mightiest man in all England with his bow, and at his death no man could spring it. This bow was a family relic in the time of William Harvey.

William Harvey's oldest son was Thomas, and Thomas's oldest son was William, and all lived at Taunton. William Harvey's fourth son was Jonathan, who lived near Taunton. Jonathan's third son was Rufus, who was born about

three miles from Taunton Green in 1760. He served through the Revolution as a "minute man," being frequently called to the service of his country, and rising to the rank of sergeant. After the termination of the war he moved to Wardsboro, Vt. (1787), where he married Sarah, daughter of John Jones. He was a man of education, evidently, as he taught school in Taunton for several years before going to Vermont. In Vermont he bought a farm and, later, was elected town clerk and justice of the peace in Wardsboro.

The oldest son of Jonathan Harvey was Thomas William, the father of the subject of this memoir.

GENERAL THOMAS WILLIAM HARVEY

This remarkable man was born at Wardsboro, Vt., July 22, 1795. He attended the village school, learned the trade of a blacksmith, and, at twenty years of age, was considered a skilled mechanic. In 1815 he went to the western part of New York State under contract to put up the machinery in a new cotton-mill which was being erected in Jamestown, a town recently founded in Chautauqua County, at the head of the beautiful Chautauqua Lake, whither he took his young wife, Melinda, the daughter of John Hayward, of Dover, Vt.

The machinery for the cotton-mill never came, but the village settlers urged him to remain among them, offering him a building lot as an inducement, and so he built a home and a forge, and became the village blacksmith. There his five children were born. He took an active interest in the growth and development of the young town, and his name occurs fre-

GENERAL THOMAS WILLIAM HARVEY

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quently in the early traditions of the settlement. He organized a train band and became its captain ; later on his interest in military affairs extended to the State and he became a Major-General of the Twenty-sixth Division of Infantry in the old New York militia. He received his commission from Governor Marcy, January 30, 1833, and for many years took an active part in the development of that organization.

With his brother Charles, who was also an excellent mechanic, he built most of the machinery for the young manufacturers of Jamestown. He remained in that town for about fifteen years and, having invented certain machinery for making screws, he went to Ramapo, N. Y., to have it built. Thither he brought his family and a few years later he settled in Poughkeepsie, where he built up a flourishing screw industry and devised and perfected many inventions. Here he was associated with Matthew Vassar and Frederick Goodell in the Poughkeepsie Screw Company. While resident in this town he was considered one of its leading and most substantial citizens. Later he moved to New York City, where he became interested

in the iron and steel business and spent much time and money in developing the iron ores of Putnam County, N. Y. At that time he was spoken of as a man "of great experience in the manufacture of iron and well known as a practical mineralogist."

He had examined and secured possession of many iron mines along the line of the Harlem Railroad ; among those that he opened at that time was the since famous Tilly Foster mine, which has proved to be one of the most valuable of Eastern iron mines. He found the ore too refractory, however, to be reduced profitably by the methods then in use. The Harvey Steel and Iron Company, with a capital of $1,000,000, was formed to develop these mines.

The late T. F. Secor was the president of that company, and General Harvey was the engineer of mines and works. This company was one of the last enterprises that he undertook shortly before his death. At this same time he was exploiting a silver mine in Vermont and lead and copper mines in New York State.

He was severely injured in the noted railroad accident at Norwalk, Conn., in 1853, and never fully recovered his powers. He died of apo-

plexy at "The Grove," Canaan, Litchfield County, Conn., June 5, 1854, aged fifty-eight.

Melinda Hayward Harvey, the General's first wife and the mother of Hayward A., was a godly little woman of good Vermont stock. She was born at Dover in that State, July 28, 1795, and was married March 28, 1815. She brought up her children in the fear of the Lord, and lived to see them all grow up Christian men and women. She shared with her husband the vicissitudes and hardships of life in a frontier town, enjoyed with him the wealth and comfort that came as a reward of his genius and labor, passed through the hard times of his later life and died in New York, September 6, 1850, aged fifty-five.

The General married, January 12, 1854, Miss Sarah Cowles, a daughter of the Rev. Pitkin Cowles, of Canaan, Conn., whose house, "The Grove," was the scene of the General's death. Mrs. Harvey survived her husband many years, beloved and respected by all his descendants.

Physically General Harvey was a magnificent specimen of manhood, standing six feet two inches in his stockings and weighing two hundred and eighty pounds. He had great

strength; a tradition is current in the family that he felled a horse with a blow on its head from his naked fist. At fifty years of age it is said that he could kick an object held at the level of his head.

He was a born leader of men. In a train band he was the captain; in a bear hunt, the chief; in a choir, the leader; in a business organization, the master mind and leading spirit. He was associated with the leaders of thought and action wherever he lived. He was active in the early management of the American Institute, was a director and president of that institution, and was invited to read scientific papers before the meetings.

Early in the forties he conducted an exhaustive series of experiments with electricity. He had at that time a machine shop, the power for which was furnished by an electro-magnetic engine. Here he was frequently visited by Professors Draper, Henry, and Morse, who at that time were all experimenting with electricity as a means of communication. His electricity was obtained from batteries of cells and at an enormous expense, and the experiment was soon abandoned. His enthusiasm

MRS. MELINDA HAYWARD HARVEY

regarding his electrical experiments was very great. In 1841 he remarked to the late Dr. Hazelton, of Jamestown, then an inmate of his family: "If you live to the ordinary age of man, you will see electricity the great motive power of the world." Many interesting developments recorded in his notes seem almost prophetic. He deposited silver on his copper plates for his batteries in an electrical bath, which was one of the earliest, if not the earliest, example of electroplating in America. He separated iron from the ore by means of magnetism, using an endless belt, with fixed magnets fastened to it, to extract the metal, but had no simple method of removing the iron from the magnet.

His son said that he devoted the last few months of his life to developing a method of making steel from the ore by one process, and had he lived but a short time longer it is probable he would have accomplished his object. At that time the desire of iron-makers was to discover the secret of "Russia" iron, and the Harveys devoted much time to experiments in that investigation. They observed so much secrecy in their experiments that the local of-

ficers broke into their shop under suspicion that they were making counterfeit coin. His last patent, granted only a short time before his death, was for a "furnace for manufacturing wrought iron from ore."

While resident in Poughkeepsie he devised machinery for, and was active in organizing, a pin-manufacturing concern, which was one of the earliest to make the solid-head pin; and late in life he invented a very successful "pin-sticking machine" for placing the pins in the paper wrapper automatically. He was also interested, with his brother Charles, in the hair-cloth industry, particularly the making of stocks, and he received a patent for a machine for weaving stock forms.

A very early invention was a "flanged spike" developed while he was still a resident of Jamestown.

EARLY SCREW INVENTIONS

One of General Harvey's earliest inventions was one of the most important. He called it the "rotary toggle-joint press," which was patented April 27, 1832. He said of it: "I am inclined to believe that I have discovered a new principle in mechanics, or rather a new application of an old principle, to wit: the knee-power press, by a rotary movement produced by the revolving of wheels, and by which a powerful press may be applied centrally upon any object desired in a more rapid manner. It is an immense power, possessing all the advantages of the screw or inclined plane, with the additional advantage of almost a total reduction of friction."

Again he says, in a letter to a business friend: "I originated a new idea in mechanics by which I can communicate a press of many tons force (fifty, if required) some 2,000 times a minute. The knowing ones at Washington have complimented the discovery as being

more important than any discovery that has been produced in the last one hundred years. What I shall be able to make out of it I cannot tell. It is adapted to making all kinds of nails, wrought or cut, brads, tacks, railroad and ship spikes, steam-boiler rivets, all other kinds, wood-screws, bed-screws, bolts, pins, type, combs, buttons, crackers, cutting files, coining money, pressing bricks, and striking all kinds of dies. You can at once see that here was a field opened for any man of genius or ambition."

He made arrangements with Messrs. I. S. Pierson & Sons, of the Ramapo Manufacturing Company, for the construction of various machines for the application of the new mechanical principle. Its application to the heading of the screw blank soon led him to the study of the manufacture of wood-screws, and he received patents for new screw machinery March, 1837. The product was the first gimlet-pointed screw, and it was made by the Poughkeepsie Screw Company.

A graphic picture of the screw industry of that time and of General Harvey's business activity, from the pen of Hayward A. Harvey,

is appended. It is a crude first draft, but is so characteristic that it is inserted without alteration:

From Hayward A. Harvey's Memoranda

The toggle-joint press was first tested at Hoe's in Gold Street, New York. Afterward an arrangement was effected for the developing of this invention with the Piersons at Ramapo, in the year 1831. The invention created a great deal of inquiry and interest all over the country; so much was this toggle-joint used, so identified was the inventor with it that he was known for years as General T. W. Toggle-Joint Harvey. . . . Through his invention of machinery for weaving stocks he became acquainted with Frederick Goodell, who was a manufacturer of cotton cloth and owned mills at Ramapo. During 1834 they, Goodell and my father, founded a copartnership, known at Poughkeepsie as the "Screw Manufacturers." During the same year he bought the Montgomery Screw Works, a small affair and very primitive. . . . The concern was closed that winter and my father commenced to get up a complete set of screw machinery, comprising a header, nicker, and shaver combined, and a threader. Before building these, they heard of a threader invented by Sloat and Springstern, which they purchased and afterward put into successful operation at Poughkeepsie in connection with my father's machines.

The header here adopted had a toggle joint with two

pair of feeding tongs, an independent cut-off with a stop to feed against ; the dies were closed by a wedge motion. They had, I think, three of these machines in those works. The nickers were arranged with four rowlets and two shaving operators to each upon one ponderous frame ; one operator to two rowlets.

The shaving was done by revolving tools, three to each blank—a back tool, an edge tool, and a face tool. They had three of these frames, making twelve nickers and shavers. The threaders were arranged with three machines to a frame and it was expected that one operator would tend the three. In this machine the blank revolved and had also the chasing motion ; the tool had but one motion, up and down, but was brought nearer at every successive cut.

Gimlet-pointed screws were made upon these machines. The operator had to put in and take out each one ; the machine, having performed its work on the blank, stopped, and when supplied with a fresh one was set in motion by the operator.

I am not able to say how many machines of this kind were made, nor the amount of screws turned out daily ; I should say about four hundred gross per day.

About the year 1837, some capitalists from New York and England bought out the interest of Goodell and paid him $100,000; they afterwards procured a charter and formed a company with a capital of $200,000. This company sent out machines to England and France, and sold their patents in those countries, I have the impression, for quite respectable prices, but not to a great profit on account of the heavy expenses attend-

ing the enterprise. My impression, from information derived from my father's old correspondence, is that they netted about $50,000.

But, to follow the home history: In 1838 or 1839 the Poughkeepsie company became embarrassed by the outside speculation (which had been very rampant just before this time) of its directors, and they formed an arrangement with a water-power company in Somerville, N. J., on the Raritan River.

At this time my father had exhausted himself financially in speculation and experiments, and was compelled to sell his whole interest, to satisfy his engagements.

Up to this time, say 1839, he had invented and constructed in Poughkeepsie a machine for pressing brick, which sold for $30,000 (I have the notes yet); a coining machine for Mexico (I have the notes for this invention, $10,000); a horse-shoe machine; a spike manufactory, having bought back from the Piersons their interest for $30,000; a machine for making hair cloth (was successful); machines for sawing down trees; a complete set of pin machinery and for sticking the same on papers, and a lot of type machinery.

Then he commenced a complete new set of screw machinery. A shaving machine was completed and a nicker and threader but partially, when the urgencies of his creditors compelled him to make some disposal of them—how, and for what, I never knew; but the whole thing was abandoned by him and the machinery went to Somerville when the machinery of the Poughkeepsie company went. The shaving machine above mentioned was never put into operation except experimentally, and

a model of it is now in the possession of the American Screw Company. It is a complete automatic machine.

He removed, in 1839, to New York and took up his experiments in electro-magnetism and reaping machines.

In the spring of 1841 I commenced the drawing for his experiment in a new set of automatic machinery for making screws, which was patented in 1846. In 1844 they commenced to build machinery for a large concern for this object. Mr. Charles Ely furnished the capital, and a concern capable of making about eight hundred gross per day was operated at Thirty-third Street, New York.

In the year 1849 it was combined with the Somerville Screw Company, the New York company taking stock of the Somerville for pay, which stock never had any market value. This concern eventually failed, and its machinery went to the four corners of the earth, it having been made up of a conglomeration of the past from every concern. There was the Poughkeepsie, then Crumb's addition came in with his long-lever die machines ; after that came Crain's Schenectady concern, having a hodge-podge of everything under the sun ; and then came the New York screw concern, to make a Babel worse confounded in screw machinery. I would say here that this New York screw concern has been the school for all screw inventors and screw manufacturers since. The Providence company secured their business through the apt scholars Sloan and Whipple. The Taunton company had a part of the machinery that was at Somerville, having bought it of them, and took time to study, but not to avoid the patents.

The closing up of the New York company did not deter my father from further efforts ; the patent was retained by Mr. Ely under an arrangement for future uses. My father had in contemplation a concern that should not only make screws, but should make their own iron and wire rods. With this in view, a company was formed, mines bought, land purchased, and a few furnaces erected, but it was still incomplete at the time of his death, which took place in 1854, caused by the railroad disaster at Norwalk.

In such a school and with such a schoolmaster did the subject of this memoir receive his training—a training from which he graduated with his eyes ever watchful for new phenomena and his mind ever open to new ideas. In mechanics the development had been in the direction of automatic machinery ; in metallurgy toward careful study and laborious experimentation with new methods. The effect of this training is evident to those of his friends who are familiar with the long series of experiments in the supercarburization of steel, which led up eventually to the armor-plate process.

When these experiments carried him beyond the practice of the text-books, and he began to talk of the conditions under which he was producing the results he was showing, the experts

of the day said, "That is impossible, the man is deceiving himself"; such criticism, however, never shook his conviction that he was on the right track and that he would produce a steel with qualities entirely different from anything heretofore produced.

The result crowns the work.

HAYWARD AUGUSTUS HARVEY

BOYHOOD AND YOUTH

Jamestown was still a frontier town in 1824. It had been founded in 1807, and, while its growth had been rapid, the surrounding forests were full of large game, and the original owners of the soil, the Indians, were plentiful. Hayward Augustus Harvey was born in the house that his father had built on the corner of Pine and Third Streets, January 17, 1824. The house is no longer standing. A contemporary describes him as a "bright, active, mischief-loving boy, when Jamestown was a boy's paradise." He attended school in Jamestown until he was nine years old, when the

HAYWARD AUGUSTUS HARVEY AT ABOUT TWENTY YEARS OF AGE

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family moved to New York City. Of his life in Jamestown he had many stories to tell, of the wild animals he would see on his way to school, and of the wild men who would come to inquire of his mother the whereabouts of the "smith."

When the family moved east he had an experience in varieties of travelling which is illustrative of the state of the country. He travelled by stage-coach from Jamestown to a point on the Erie Canal, where they embarked on an "express packet." These fast boats bore the same relation to the ordinary canal-boat that a Providence line steamer does to a freighter. They were luxurious relatively, with handsome lively teams, and the passengers entertained each other with music and dancing, speech-making, etc., anything to pass the time away.

At Schenectady the canal was left and the party rode to Albany on the new steam railroad, which was the first one built in New York State. From Albany a steamboat took them to New York City. At that time the best hotel in town was in Cortlandt Street, whither they went.

The General had some machinery building

in Ramapo, and thither the family soon went, travelling by way of Paterson on the horse-railroad that preceded the Erie Railroad.

Of the life at Ramapo, there are only memories of the pleasant country home.

When he was twelve years old the family moved to Poughkeepsie, and he attended school at "The Academy on the Hill" and later he entered the New Paltz Academy for the purpose of preparing for Yale College. This purpose was, however, frustrated by the great financial depression of the later thirties, which prevented his father's carrying out the plans he had arranged for his education. Instead of going to college he went into the factory at Poughkeepsie, where he studied and practised draughting and the various branches of mechanical engineering. It is fortunate that it was so. No school or college at that day could have given him the knowledge of mechanics and of metallurgy that he acquired from being a witness of and participant in the experiments of one of the most active and expert mechanicians of the day.

As a schoolboy he entered into all outdoor sports with great zest. He was a very strong

man physically, although entirely untrained, but the active out-of-door life among the boys of the New Paltz Academy laid the foundation for his great strength. His love for the open air and outdoor sports was always with him, and he was never satisfied unless his horse was a little better than any that he was likely to meet.

The family were all fond of music, all had good voices and the sisters received a good musical education, as was considered proper at that time. Hayward could play almost any musical instrument as a young man, and this without any regular instruction; he also cultivated his voice and became very fond of church music, devoting a good deal of attention to it throughout his life. Probably few men, even skilled musicians, derived as much pleasure and consolation from music as he did.

The piano was a solace and diversion to which he turned whenever business was harassing, or to relieve the suspense of awaiting the results of experiments or negotiations. He was the leader of the choir in the Fourth Street Presbyterian Church of New York for several years, and had a singing-school of the old-fashioned sort in connection with that church.

His brother-in-law, Mr. Cornelius Winant, has written of that time, and from his letter the following has been taken :

My Dear Nephew :—

When I first knew your father, he was a bright, interesting young man of about eighteen or nineteen years. I may have known him previous to that, but it was not until he became a visitor at our house that he impressed himself on my mind. He was then a slightly built young fellow of most engaging manners and fine appearance, dressing in good taste. He was a lover of music, a fine singer and a good pianist, and his society was much sought after by the young people. He was genial, kind-hearted, and considerate of others to a marked degree. He appeared to have no faults, certainly no bad ones, and living with him and your mother as I afterward did for several years I of course became very intimate with him and much attached to him. I thought then, and do still, that he was as near perfect as any man I ever knew. My association with him during those years, at a time when my character was forming, was most excellent and beneficial, and I have always felt that I owed him a great debt in this direction. . . .

How well I remember his first invention—at least I think it was the first. He had established himself as a manufacturer of wire in Thirty-third Street, east of Third Avenue. Finding himself supplying a certain size of wire to be bent into blind staples, he thought he could make an automatic machine to do the work. This

he did, and found an abundant sale for the product, until he thought he had furnished a supply that would satisfy the market for years, so he sold the patent-right to his friend Frank Upham. Upham hired a boy and set him at work, and lived on the profits of that little machine for several years.

Truly yours,
CORNELIUS WINANT.

Later in life Mr. Harvey continued his interest in church music and for many years was precentor at the Trinity Congregational Church, at Orange, N. J.

After the formation of the New York Screw Company of which his father was president, he entered the service of that company as draughtsman. The English patent officials of that day pronounced his drawings to be the best that they had received from America. It was about this time that he made his first invention. This was the machine for making blind staples referred to by Mr. Winant in the letter above quoted.

He was interested in the blind staple industry for over twenty years, having had a patent issued to him for a corrugated blind staple as late as April 2, 1867. He also invented about

that time a hay-cutter, for which he received a silver medal at the exhibition of the American Institute in 1847.

He was married December 29, 1849, to Miss Mary Matilda Winant, daughter of Cornelius Winant, of 649 Fourth Street, New York City, whom General Harvey, in a letter describing the event to his brother and sister in Vermont, speaks of as "an eminent shipbuilder."

After the wedding the young people went to Somerville, N. J., to live, where Hayward took charge of the wire-mill connected with the screw company of that town. In 1850 he had returned to New York City, where he established a wire-mill himself. Before the business was fairly started he was burned out, and he then entered into the employ of the Harvey Steel and Iron Company, which his father had recently organized. Their works were established in Mott Haven, near the northern end of the railroad bridge over the Harlem River. The stack is still standing, a monument to the engineering skill of the Harveys. The ground was swampy, and when the foundation for the great chimney was to be built it was found that the stones disappeared as fast as they

HAYWARD AUGUSTUS HARVEY AT THIRTY-FIVE YEARS OF AGE

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were thrown upon its surface. There seemed to be no bottom to the swamp. A large timber frame-work was built, and upon this was erected the foundation; as it sank into the mud the masonry was carried higher until at last it ceased to sink, and then the stack was built up. Its stability is an evidence of the good construction. He was also interested with his father in an experimental iron plant which they erected in East Canaan, Conn., near the town of Norfolk, which was called the Wangum Iron Company. What the object of their experiment was is not now clear. They were experimenting in making steel direct from the ore at this time, and as they tried many different ores found in that locality it was probably the peculiar qualities found in those ores that caused them to build their plant there.

The death of General Harvey, however, interfered with the success of these two companies and they soon discontinued their operations.

After the death of his father, Mr. Harvey devoted himself to developing some of the former's unfinished projects. The death of his wife occurred on June 26, 1857, and his home

being thus broken up he had no permanent abiding-place until his second marriage in 1865. During this period of about ten years he was engaged in many enterprises more or less successful, and he made several inventions —among others a "railroad chair," patented December 25, 1859; but his chief operations had to do with the American Screw Company of Providence, R. I. Soon after his father's death he convinced himself that the screw companies in that city were using machinery which infringed his father's patents. Accordingly, he set about an investigation, and soon collected proofs sufficient to cause the officers of the American company to offer a compromise. As narrated by that company's president, Mr. William G. Angell, "while negotiations for a union of the two companies (the Eagle and the New England screw companies, both of Providence, the immediate predecessors of the American Screw Company) were in progress, proceedings had been begun against the Eagle company by the heirs of Thomas W. Harvey for infringement of his patents. These claims would have applied also to the New England company. Both companies had made use of

principles covered by the patent for automatic screw machinery, patented by Harvey, May 30, 1846. The claim against both companies was admitted and settled after the organization of the American Screw Company on terms fixed by arbitration."

As an outcome of this compromise Hayward A. Harvey was put on the salary list of the American Screw Company and acted as their confidential agent in many of the negotiations which resulted in that company's securing the monopoly of the American market. This connection was severed about 1863 by the American company, through the efforts of some of its directors, who did not appreciate how serious a rival they were liberating to their own detriment. In a very short time he had invented a full set of new automatic screw machinery, headers, shavers, nickers, and threaders, and was quickly successful in interesting New York capitalists in a new screw company which was called the "Continental" and which was formed in 1865.

On June 21, 1865, he married Miss Emily Alice Halsey, the daughter of Captain Charles Halsey, of Bridgehampton, N. Y., a sea captain.

He then took up his residence in Orange, N. J., where he remained until his death, which occurred August 28, 1893.

Mr. Harvey took a great deal of interest in the town in which he lived. Previous to the Civil War he had been an adherent of the Democratic party. After the war he supported the Republican party, and took an active share in the local management, serving frequently on the local committees. He served two terms as a member of the Common Council of the city of Orange, being elected first in 1873 and again in 1879. He was intimately connected with the introduction of water and sewerage into the city. He was one of the original Water Commissioners, and also a member of the preliminary Advisory Board of citizens who formulated and devised the system of sewerage and drainage which was afterward put in operation.

As a citizen he was a quiet, unassuming, law-abiding member of the community, always ready to do his share, giving his time, labor, and money freely for whatever purpose seemed likely to improve the happiness, comfort, or well-being of those around him ; doing every

task that he assumed honestly and thoroughly, ever ready to give of his means to the furthering of any charitable plan or philanthropic institution.

THE CONTINENTAL SCREW COMPANY

As stated above, in 1865, having invented a full line of screw-making machinery, Mr. Harvey interested a number of New York capitalists, and proceeded to organize a screw company with this title. It was a strong company, with a capital of half a million dollars. They erected works in Jersey City at the corner of Washington and Eighth Streets.

This was a complete screw-making plant, including a wire-mill. Their selling agents were Hart, Bliven, Meade & Company, of New York; Mr. Bliven being the active head of the Screw Company. They commenced making screws immediately, and soon made themselves felt in the market as the most important rivals of the American Screw Company.

After four or five years of existence, the lat-

ter company bought them in and absorbed the Continental, sending the machinery to Providence and selling the buildings to the Lorillards for their tobacco business, who enlarged the buildings to twice their previous capacity and are still occupying them.

Mr. Harvey was the Manager of this Company, and closely associated with him in its management was Mr. Edward E. Quimby, who for a time was the Superintendent, and who had been a personal friend from early manhood.

From this time on, Mr. Quimby was intimately connected with Mr. Harvey and his work. He drew up his patent specifications, acted as his attorney in disputed questions before the Patent Examiners and as his expert in litigations. He was constantly consulted in the new business enterprises that developed from his inventions, and was always a stanch and loyal friend, a wise and safe counsellor.

HAYWARD AUGUSTUS HARVEY AT FORTY-SIX YEARS OF AGE

OTHER INVENTIONS

After the sale of the Continental Screw Company to the American Screw Company, Mr. Harvey became connected with the latter company in an advisory relation which continued for some years. He was also interested in, and a director of, the Peru Steel and Iron Company and the Hart Manufacturing Company. He was associated in these companies with the late Charles Bliven and the late William H. Gunther. He devoted most of his time to the Peru Steel and Iron Company, a concern with mines and forges at Clintonville, N. Y. It was for a number of years a very successful business enterprise, but the panic of 1873 put a stop to its dividends, a receiver was appointed, and though it partly recovered itself in the boom in iron that occurred in 1880, it did not live long after that period.

From 1865 to 1871 he devoted much time and money in an attempt to secure from Congress an extension of the lifetime of General

Harvey's patents issued in 1846, which had been used by the New England manufacturers, and were considered to be the basic patents in automatic screw machinery. The attempt was a failure, although the bill passed the Lower House in 1871. Mr. Harvey always regretted the time wasted in these endeavors, which it is true would have resulted in the General's heirs realizing some benefit from these inventions, which had been appropriated and made the basis of enormous profits by others, but which had never yielded the General or his family any return. This is often the case with revolutionary inventions.

For some time he had been devoting his attention to wire nails and bolts, and in 1874 he patented a bolt with a varying pitch of thread on which an ordinary nut should be fitted. The upsetting of the threads when the nut was screwed up locked it firmly. This was called the "peripheral grip bolt." In 1876 the Harvey Manufacturing Company was organized to make these bolts. The gentlemen who were first interested in this company failed to raise the necessary capital and their interest was bought out by Mr. Harvey. About this time

Mr. Benjamin G. Clark and Mr. Theodore Sturges became acquainted with Mr. Harvey and his inventions, and interested themselves in this company. After a few years its business was taken up by the Harvey Screw and Bolt Company, which concern, however, was dissolved before doing any great amount of business, and the bolt patents and business were bought by the Kansas City Bolt and Nut Company, which concern is still making and selling these bolts for railroad use.

THE ROLLED SCREW

During this time Mr. Harvey devised a new system of machinery for making screws. Hitherto all screws had been made by cutting the threads on the blanks with a sharp tool. All of his father's and his own previous threaders had thus "cut" the thread. He designed a machine for rolling the thread upon the screw-blank, and in this machine the thread was partly rolled into and partly pressed out from the surface of the blank by a so-called cold forging process. These screws have a sharp

central point, which with the large thread and small neck make the entrance into the wood easy. One variety of these screws had two bosses on the surface of the head instead of a nick. The Harvey Screw Company was organized in 1881 to manufacture these screws, but soon afterward was merged into the Harvey Screw and Bolt Company, which also took the bolt business of the Harvey Manufacturing Company. The late United States Senator William H. Barnum was actively interested in this combination, and an expensive foundation was built at Lime Rock, Conn., it being expected that large works would be erected there. The foundation, however, remains as it was. Internal dissensions ensued and the company dissolved, as has been mentioned, the screw patents and machinery being sold to the American Screw Company in America, and to the Nettlefolds in England. These inventions were fundamental, and changed the methods of screw-making, both in this country and in Europe. The cold-forged screw is now the standard.

Mr. Harvey's claim to priority and originality in this invention of threading screws by

rolling has been attacked by those who followed him and profited by developing the new system of screw making.

We can quote no less an authority than Mr. Edwin G. Angell, the President of the American Screw Company, in support of his claims.

In a letter written to Mr. Harvey on July 18, 1887 (after the purchase of the United States patents by the American Screw Company), in which the purchase of stock of that Company by Mr. Harvey and his friends in New York was being urged, Mr. Angell says : "The more I think of it, the more I desire you should be interested with us, because you are entitled to credit in laying the foundations for us to work upon, something as your father did for the automatic threading (cutting) machinery."

Surely there is no one more familiar with the history of the art, nor anyone more conversant with the facts of the case, than Mr. Angell.

A thread-rolling machine was exhibited by Mr. Harvey in England about this time and, besides receiving the Gold Medal at the International Inventions Exhibition in London, re-

ceived highly flattering notices from the daily press and from many technical journals. The following is from the *Iron Age*, September 3, 1885:

The Harvey Rolled Wood Screw.

The fact that wood screws have been manufactured by rolling is one generally known to the trade in this country, and those who have used rolled screws have testified to their superior excellence. It is also known that they are practical screws, possessing certain advantages over screws with cut threads. It has been reported that their manufacture would be undertaken on a large scale, but as this was not done we presume the matter has passed out of the minds of those for whom the subject has special interest. The facts we give below will, we are sure, be found of general trade interest.

The first exhibition of the Harvey screw-threading machine was made at the International Inventions Exhibition in London, where it was awarded the gold medal. This machine and its product excited great interest, and, as it is an American machine in every particular, a few extracts from comments in recent issues of leading English journals will be read with satisfaction. *Engineering* of August 21st says:

"A very ingenious, and at the same time exceedingly simple, machine for the manufacture of wood screws is shown in the western gallery of the Inventions Exhibition. It differs from all existing machines for the same

purpose in that the threads are not cut, but rolled—that is, the wire blank is pressed into the final form without loss of material, the fibres being squeezed into the alternate projections and depressions of the screw-thread. From this apparently simple alteration in the mode of manufacture there result a great many advantages. Firstly, there is a considerable saving of metal, 1 ton of wire serving to make 1,800 gross of No. 10 rolled screws, 1¼ inches long, while it will only produce 1,066 gross of cut screws. Secondly, the threads stand out beyond the original diameter of the wire, and consequently beyond the shank; hence it is not necessary to send a second bit down the hole in the wood to enlarge the part intended for the reception of the shank. Indeed, in many instances no hole is required, for the 'gimlet point' actually answers to its name, and will lead forward without any preliminary assistance. We have seen one 1¼-inch screw put up by a screw-driver into a solid block of beech right up to the head without difficulty. Thirdly, the threads are stronger for the rolling process, the fibres being merely bent, and not cut, as in the ordinary screw. This may not be regarded as a very important point, as wood always strips before the screw which holds it. But when the Harvey screw is employed, the holding power of the threads in the timber is increased, as they extend the whole depth of the hole, and are not destroyed at the mouth by the pressure of the shank. A fourth advantage is that there is a saving of fifteen per cent. in the cost of production. It is impossible to watch the machine without becoming impressed with its great merit. It turns out its work

with marvellous rapidity, and produces a screw which is cheap to buy, easy to insert, and which is distinctly superior in many respects to those already in the market."

Iron of the same date says :

"Not only does this machine claim attention as a novelty, but in a far greater degree as one of the most simple, ingenious, and effective pieces of mechanism of its class we have ever seen. The machine is not a large one, but it gets through a great amount of work in a very short time. The screw-threads are formed by rolling the blanks between two metallic surfaces, both cut so as to form dies which produce the thread. This is effected without cutting or waste, and, in the machine we saw operated, at the rate of a gross, or 144 screws, per minute. The screw thus formed is found to possess many advantages over the ordinary screw with the cut thread. These advantages, besides being apparent on the face of it, are admitted by experts who have thoroughly tested the Harvey screw. In the first place, it has a true gimlet point, drawing the screw into the wood in a straight course, and doing away almost entirely with the use of the gimlet. The thread is found to be much stronger, the metal being rolled up and compressed. In the ordinary screw at present in use the fibre is cut and thereby weakened. Another point of great value is that the neck of the Harvey screw is of smaller diameter than the thread, whereas in the ordinary screw, the neck is larger than the thread, necessitating in hard wood the use of two gimlets to avoid splitting. The extent and importance of the screw trade

are hardly known, but they will be understood when we mention that in England alone screws to be used in wood are made to the number of 130,000 gross per day. The Harvey machine will make 1,800 gross of No. 10 1¼-inch screws from 1 ton of wire, whereas the old system produces only 1,066 gross, showing a loss by the latter of 734 gross in 1 ton of wire. We understand that Messrs. Ladd & Co. intend putting down a plant for the manufacture of these screws, which will have sufficient capacity for meeting the entire demand of the trade. The screw-threading machine recently formed the subject of special inspection by a party of gentlemen interested in the production and use of screws and bolts, and its working elicited from them expressions of unqualified approval, which we unhesitatingly indorse. It is almost superfluous for us to add that the gold medal of the exhibition was awarded to this ingenious invention. It would have been strange had it been otherwise."

The *Architect*, speaking of this machine, says :

" The Harvey machine differs from the old system in this respect, that, whereas the latter cuts the blank to form the thread (causing a great waste of metal), in this new machine the threads are rolled by compression. It is a small and exceedingly simple machine. By the old system 1,066 gross of 1¼-inch No. 10 screws could be made from 1 ton of wire, at the rate of 15 screws a minute per machine ; whereas the Harvey machine has an outturn of 1,800 gross, at the rate of 1 gross per minute, thus effecting a saving of 734 gross in 1 ton of wire, and doing the work of 10 machines of the old

method. The screw made by the Harvey machine possesses the following advantages: It has a true gimlet point, thus drawing the screw into the wood in a straight course, and doing away almost entirely with the use of a gimlet. The thread is found to be much stronger, the metal being rolled up and compressed. In the ordinary screw at present in use the fibre is cut, and thereby weakened. Another point of great value is that the neck of the Harvey screw is of smaller diameter than the thread, whereas in the ordinary screw the neck is larger than the thread, necessitating in hardwood the use of two gimlets, to avoid splitting."

The London *Morning Advertiser*, of August 19th, says :

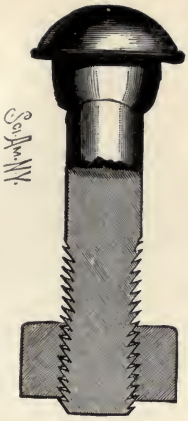
"The Harvey patent screw and bolt threading machine is exhibited at No. 1144, in the west gallery, at a stand which occupies an area of only a few square feet, but it turns out a prodigious quantity of work in a given time, and it is claimed for its results that they are in every respect superior to those produced by any existing machinery having the same object in view—the manufacture of the common screw. The process of manufacture hitherto adopted consists in cutting the thread out of the solid blank, and it is objected to this that there is a waste of material, and that the metallic fibre is weakened. A further objection has reference to the form given to the article. The thread is cut on a conical surface, which is continued from the end of the thread to the head of the instrument, into which the screw-driver is inserted. The shank of the screw thus acts as a wedge with a very small angle, which con-

sequently has a strong tendency to rend the material into which it is forced. The Harvey machine, accordingly, is not a screw-cutter, but a screw-roller. It does not cut the screw out of the solid metal, but rolls the solid metal into the required form, and delivers the article in its finished state, free from the imperfections to which reference has been made. The machine exhibited yesterday turns out its work at the rate of a gross per minute, which, we were informed, is much greater than under the ordinary methods of production. The Harvey machine will make 1,800 gross of No. 10 1¼-inch screws from one ton of wire, whereas the old system produces only 1,066 gross, showing a loss by the latter of 734 gross in one ton of wire. During several hours' trial of the machine it worked most satisfactorily, and received the approval of several practical men who were among the numerous body of spectators who watched the working of it."

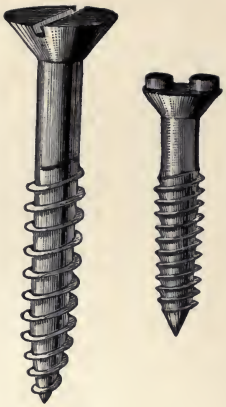
The London *Morning Post*, of August 20th, says that the Harvey machine "is invariably surrounded by a crowd watching with amused interest the simple operations which it goes through with almost human sagacity. It is not a large machine, but it does an amazing amount of work, turning out about one hundred and forty-four screws a minute. This screw has a true gimlet point, driving into the wood in a straight course, thereby doing away almost entirely with the use of the gimlet. The same machine threads iron and steel bolts equally as well as screws for wood."

The influence which the Harvey machine is likely to exert in the American screw-trade is admittedly great.

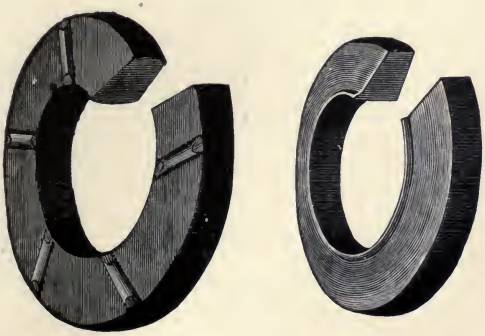
The invention is the product of many years of thought and experiment, and the various parts of the machine, with the processes and the product, are the subject of about twenty-five American patents properly duplicated in Great Britain and on the continent of Europe. The inventor, Mr. Hayward A. Harvey, of Orange, N. J., has been all his life identified with the screw business. His father, General Thomas W. Harvey, was the inventor of the automatic screw-cutting machines, the principles of which gave to the American Screw Company their long and lucrative monopoly of the wood-screw business of this country. Mr. H. A. Harvey has contributed largely to the growth of the screw-cutting industry, having taken out over thirty patents relating to screw-cutting before he turned his attention to the rolling process. In fact, it may safely be said that there is not a screw-machine in the world that does not embody some invention of one of the Harveys, father or son. Briefly described, the Harvey process consists in rolling, pressing, or moulding the screw-thread partly into, partly up from, the screw-blank, in contradistinction to the old process, in which the thread is formed by cutting into the metal of the blank. This is accomplished by rolling the blanks between two dies—one rotating, the other stationary, and each having on its surface grooves corresponding to the screw-threads. These grooves form the thread progressively on the blank, and the sharp, well-centred gimlet point is formed in the same operation. The machine itself is no less interesting than the process and the product, being full of remarkably ingenious



PERIPHERAL GRIP BOLT



ROLLED SCREWS



WASHERS

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automatic contrivances. We hope soon to give a detailed description of it, with drawings.

It is well known that every cutting tool begins to deteriorate as soon as it comes into use. Especially in working metal is the first product of the cutting tool the best product. The succeeding products depreciate steadily, owing to the wear of the cutting tool. This is such a fixed and recognized fact that in the making screws by the cutting process it is absolutely necessary to employ a large force of "assorters" to separate the screws of first quality from the "seconds." In the Harvey rolling process there is an instrument which does not deteriorate so as to affect the quality of the product. If one thread on the roll fails to do its duty, a score of following threads stand ready to remedy the defect as the screw proceeds to its finish. The operation of "assorting" is reduced to a minimum—in fact, the number of "seconds" made is barely appreciable. In the Harvey machines dies have been used constantly for more than a year without visible deterioration.

In regard to rapidity of production, one Harvey machine will produce one hundred and fifty 1½-inch No. 13 screws per minute, against six or seven screws made in a cutting machine, the two machines being of about the same cost.

The economy of rolling is important. The entire waste from cutting (about twenty-five per cent.) is obviated. In fact, there is no waste except that in the preliminary processes of heading, shaving, and nicking. The rolling process goes even further than this. A cut screw can evidently have a thread of no larger di-

ameter than the wire of which it is made. The thread of the rolled screw is larger than the diameter of the wire, showing a gain in size on the screw list of two to four numbers. For example, No. 13 screws are made out of No. 10 screw-wire. In brief, there is a gain of twenty-five per cent. in selling price, and the raising of the thread pays for the wire. The heads of the screws are brought up to correspond to the gauge of the thread.

The product is one which is in every respect satisfactory. The gimlet point is sharp and perfect and readily enters the wood without preliminary boring. The thread is deep and has a gradually increased holding power, as many experiments have shown. The neck being of less diameter than the thread is an important advantage. The splitting of wood and the bursting of the head so common in driving screws into hard wood is entirely obviated. The neck will follow without resistance the opening made by the thread. Objection is sometimes made that the neck does not completely fill the hole bored for the screw. The answer to this is that if a hole is bored at all it should be no larger than the neck, thus insuring the hold of the thread. If no hole is bored, the fibres displaced by the thread will close in around the neck. This, however, is a matter of no consequence. The hold of a screw depends wholly upon the thread and head, and so long as the neck has the full strength of the blank it is strong enough. A diameter of neck equal to the gauge of the thread is excessive. Theoretically it should be no larger than the core of the threaded part of the screw, since if

it be larger it must offer considerable resistance to the tendency of the thread when the screw is turned to draw the neck into the hole made for it. Many years ago attempts were made to improve cut screws by turning down the necks to the gauge of the cores. The improvement was obvious, but the cost of the operation was so great that it was impracticable. Had it been possible to do this without materially increasing the cost of manufacture, all cut screws would now be made with necks as much smaller than the gauge of the thread as is shown in the product of the rolling process. It is probable that before very long the manufacture of rolled screws will be established in this country on an extensive scale.

During this period of great activity in devising automatic machinery, Mr. Harvey designed several different kinds of washers for bolts. The most successful of these was the spiral-ribbed washer, which was manufactured by the National Lock Washer Company. Within six months this company was paying substantial dividends, and has continued to be a very profitable property.

In 1891 the American Washer and Manufacturing Company was formed to manufacture other products of his inventive skill, viz. : the Harvey ribbed washer and spikes. His death,

about one and a half years later, prevented the completion of the spike-making machine, and this company has confined its business to the manufacture of washers.

These were very prolific years; at the time of his death he had partly finished a complete and entirely new system of machines for making screws. He believed that this new system when complete would materially reduce the cost of manufacture.

Like his father, he died when his mind was in full fruition.

THE HARVEY STEEL COMPANY

In 1885–86 Mr. Harvey had an experimental shop in Brooklyn. Here he conducted a great many experiments with bolts and nuts, and while thus engaged he conceived the idea of hardening the surface of bolts and nuts which he had previously cast out of low steel. As he described it, he attempted to "steelify" the threads. These experiments as to the bolts and nuts did not lead to anything, but did result in his obtaining a peculiar product which pre-

HARVEY STEEL COMPANY'S WORKS AT BRILL'S STATION, NEWARK, N. J.

sented some very interesting qualities, and he succeeded in making out of a cheap grade of Bessemer steel, razor blades which were in all respects equal to the best refined steel.

Mr. B. G. Clarke and Mr. Theodore Sturges were immediately interested in this new product, and these gentlemen, with Mr. Harvey, organized the Harvey Steel Company, on November 15, 1886, for the purpose of developing this new process of making fine steel out of low steel or iron, and, in the event of the process proving practicable, to refine and sell steel. Patents were taken out on the process and furnaces erected in Jersey City in June, 1887, at 315 Washington Street, for the purpose of manufacturing, from a cheap grade of steel, low in carbon, a steel suitable for tools, cutlery, etc., for which heretofore it had been necessary to use an expensive crucible or cemented steel.

They commenced immediately to make file and tool steel. The works were moved to Newark, Brill's Station, in 1889, and here were erected fourteen Harvey furnaces, six reheating furnaces, rolls, hammers, and the usual appurtenances of a rolling-mill.

The file and tool-steel part of the business

was abandoned in 1892 on account of low prices and great competition.

In addition to the treatment of low steel in rods, a large variety of commercial articles have been "treated," such as forks, steels, parts of bicycles, jaw-plates, rings and balls for ore-crushers, tires or shells for rolls, rolls for rolling metal, punches and dies, railroad frogs and crossings, and plates for safes and vaults.

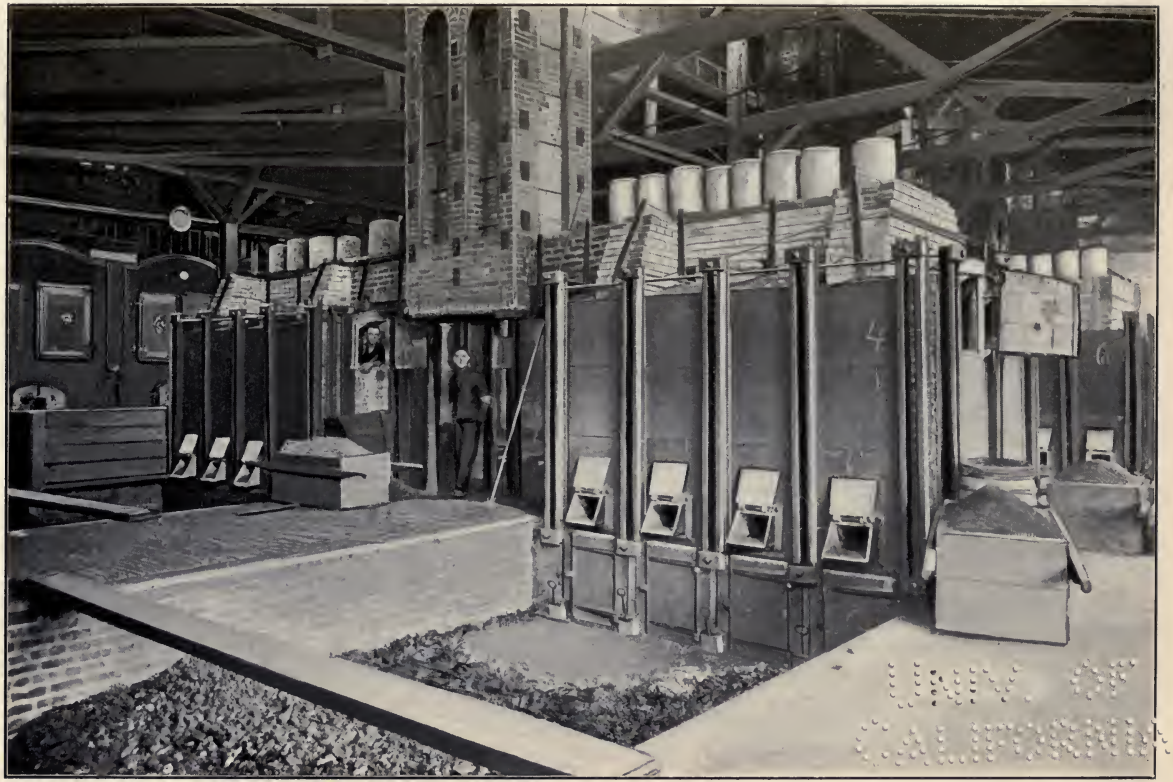
In most of these cases the treatment has proved a great success; in certain cases, however, the treatment has increased the cost beyond the point where profit was possible, owing to the necessarily low selling price of the articles.

The first officers elected were: H. A. Harvey, *President;* Theodore Sturges, *Secretary and Treasurer.* The Board of Directors consisted of: H. A. Harvey, Theodore Sturges, Benjamin G. Clarke, and Percy R. Pyne.

Mr. Harvey was President from 1886 to 1891; General Manager from 1891 to 1892; again President from 1892 until his death.

Mr. B. G. Clarke was President from 1891 to 1892, his term of office being terminated by his death.

In 1889 Mr. Harvey treated a block of steel



INTERIOR OF HARVEY STEEL COMPANY'S WORKS, SHOWING HARVEY FURNACES

with a view to give it great power of resistance to blows and strains which might tend to pierce or break it. This was a long-sought-for desideratum in armor-making, and this was the object he had in view.

Mr. Harvey's experiments were brought to the attention of the Navy Department in May, 1889, and at his request they furnished him a small plate six inches in thickness, which was treated at the Company's works in Newark, hardened in Washington by Mr. Harvey, and tested by the Ordnance Department at Annapolis. This was the beginning of a large number of tests made to determine the value of the new process of making armor. The history of the development is outlined in another place.

The new process was called "Harveyizing" in America and "Harveying" in Europe; two new verbs had been added to the technology of steel-making.

The Steel Company effected an agreement with the United States Government and introduced the new armor into Europe, where it was eventually received with great enthusiasm, and founded three daughter companies for con-

ducting the business. All this, however, was not accomplished prior to Mr. Harvey's death. Already the Steel Company had lost Mr. Clarke and Mr. Sturges by death, and Mr. Percy R. Pyne, who had been the largest stockholder and a member of the Board of Directors, had retired from active business. When, therefore, in August, 1893, Mr. Harvey himself died, it left the Company bereft of all the original officers, except Mr. S. S. Palmer, an early member of the Board, and who was elected President in 1894. The succeeding year was devoted to perfecting the European organizations.

In December, 1894, the Bethlehem Iron Company made a contract with the Government of Russia agreeing to supply Harveyed armor-plates. As this company had no license from the Harvey Steel Company to use the process, a suit for an injunction was instituted in the United States Circuit Court.

Suit was also brought for infringement against the Carnegie Steel Company. These suits were settled October 5, 1897, and decrees against both companies, sustaining the validity of the patents and enjoining them from using

the process or vending the product, except under license from the Harvey Steel Company, were duly entered.

Both of these companies took licenses acknowledging the validity of the patents and agreeing to pay royalty on all armor manufactured for export.

The *Iron Age*, October 7, 1897, said: "The result of these Harvey suits has been awaited with much interest in this country and in Europe. As is well known, all the governments of Europe are using Harveyed armor-plates, and the process has been patented all over Europe. The settlement of these suits is therefore a matter of great importance to the industrial world."

HARVEYED ARMOR

The history of armor-plate making has been from the beginning a contest between the improvements in the armor and improvements in the gun and projectile. When the sides of ships were first covered with iron plates in the early sixties a wonderful advance had been made over the wooden ship. To meet this advance the gun was strengthened and enlarged, the powder improved in quality and the charge increased; the projectile was hardened, changed in shape, and increased in weight; to meet this again, the armor had to be increased in thickness, so that while in 1861 four and a half inches was considered sufficient, in 1879 the British ship of war Inflexible had part of its armor twenty-four inches thick, backed up by seventeen inches of teak wood. As this was not found protection enough and made the ship top-heavy, there were many variations tried. The "sandwich armor" was composed of alternate layers of 6½-inch iron plates and five inches of teak wood.

Steel was used in place of iron; but steel was found to be too brittle, if adequately hard; iron too soft. Then compound armor was devised to meet the two requirements; one, a hard surface to keep the projectile out, and one a tough back that would not break up under the impact. This compound plate was a high-carbon plate welded to one of low steel or iron. Compound plates proved, however, very deficient, owing to the tendency of the two parts to separate at the weld when struck. Other manufacturers endeavored to toughen the steel by adding nickel or other substance to it. Nevertheless the power of the gun and the projectile kept well in advance, and it had been decided by ordnance experts that further increase of the size of the gun was unnecessary.

However, the conditions essential to the success of the plate had been demonstrated. What was wanted was an extremely hard surface to take up the impact and pulverize the projectile, and a tough back to sustain the hard face and prevent it from going to pieces, and some means of uniting the two under conditions which would prevent the separation of one from the other at the joint.

At this stage of the contest the United States decided to have a new navy and to armor its ships with the best armor that the world could furnish ; to be made, moreover, on American soil. Consequently, the two great iron firms of Pennsylvania were encouraged to put up large armor-making plants. This they did ; and now arrived the time when a competitive test should be made of the different kinds of foreign armor after which the new American armor should be modelled.

The competitive test was ordered to take place at Annapolis in September, 1890. Three plates were to be tested ; two from Schneider & Company, Le Creuzot, France—one being a nickel plate—and a compound plate from Cammell & Company, Sheffield, England.

Prior to this test, however, in June, 1890, a test had been made of a small 6-inch Harveyed plate, already mentioned, made by the Linden Steel Company, Pittsburg, and treated by the Harvey process at the Harvey Steel Company's works at Newark, N. J. This plate had been cut in two, and one part treated and the other part left untreated. The treated part was hardened by Mr. Harvey at Washington,

and both pieces were tested at Annapolis. The untreated part was perforated; the treated part was uninjured. The problem had been solved before the great competitive test had taken place, and the fact demonstrated that the armor for the new American navy was to be of American origin, and to give fifty to seventy per cent. better protection than could be furnished by any old-world armor.

The September trial only developed the value of nickel as a toughening agent.

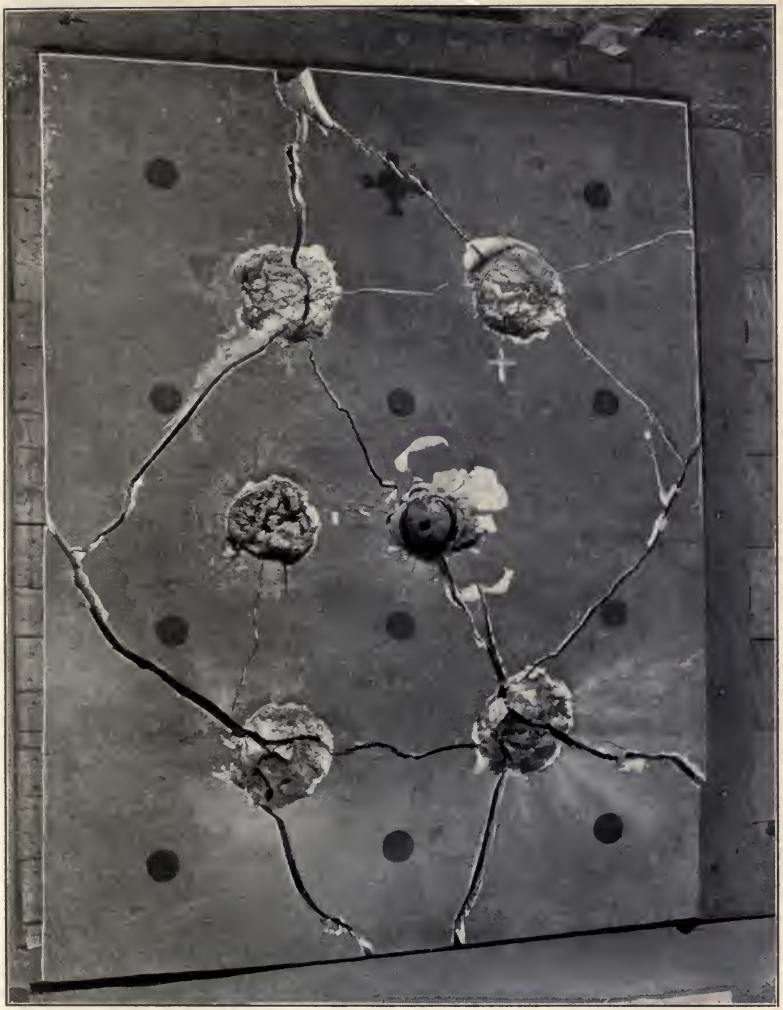
The success of this Harveyed plate induced the Navy Department to procure a Schneider 10½-inch steel plate, and to place it at Mr. Harvey's disposal in a carefully fenced-off space in the Washington Navy Yard, and here with his own workmen, at the expense of the Department, he built a suitable furnace, supercarburized the plate, and afterward chilled the supercarburized side by sprinkling. This plate was tested in February, 1891, and proved a success.

The Chief of the Bureau of Ordnance, Captain W. A. Folger, in his report for 1891, says: "These results are remarkable and indicate to the Department a probability that in this treat-

ment has been found the means of producing the ideal armor-plate, a hard front compounded with a tough back, without any weld or other line of demarcation between the two."

This plate was attacked by seven 6-inch armor-piercing shells from a 6-inch gun, the striking velocity being 2,065 foot seconds. All the projectiles were broken up and there was practically no penetration except at the centre, where it was afterward made quite certain there had been a failure to harden properly owing to scale.

The Department immediately determined upon a series of comparative tests between Harveyed and un-Harveyed plates made in this country. Accordingly five plates were ordered from the Carnegie Steel Company, and three from Bethlehem ; and under the supervision and instruction of Mr. Harvey at the respective works of these companies, furnaces were constructed and the plates supercarburized and hardened. The facilities at these works were not competent for the proper chilling of these plates, so that only parts of each plate exhibited the normal condition of a Harveyed plate. The results were, however, conclusive that the Har-



THE SECOND HARVEY PLATE

A 10¾-inch Schneider all-steel plate, treated at Washington, D. C., February, 1891. Tested at Annapolis. The plate was cracked, but none of the projectiles penetrated it except the fifth shot, which went partly through. At this spot the plate had not been tempered owing to scale.

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veyed plates were far superior to those which had not been treated. Numerous other tests were ordered, and on July 30, 1892, a 10½-inch Harveyed nickel plate made by the Bethlehem Company was tested on the proving ground near Bethlehem, Pa. The plate was attacked by five 8-inch Holtzer projectiles, each weighing two hundred and fifty pounds. The projectiles were pulverized, and the plate was uninjured, the tip of the projectile penetrating about three inches and fusing with the metal of the plate. This has come to be recognized as the normal reaction of a Harveyed plate.

Naval officers pronounced this "the most wonderful armor-plate ever made."

The Secretary of the Navy in his report said, "Never before these trials had any armor-plate in the world been subjected to such a test as was represented by these five blows of a total energy of 25,000 foot tons."

HAYWARD AUGUSTUS HARVEY

From the New York Times, July 30, 1892.

Very Tough Armor-Plate.

MAMMOTH PROJECTILES COULD NEITHER CRACK NOR PIERCE IT.

Bethlehem, Pa., July 30th.—The first armor-plate test on the proving grounds of the Bethlehem Iron Company took place to-day. The test was a very successful one. However hardy were their plates in former tests, which have heretofore been made at Staten Island and Indian Head, this surpassed all. Of the five powerful shots fired into its comparatively small surface, no one, nor all combined, effected any material damage. The projectiles simply produced small depressions on the surface of the plate, and made not a single crack.

Commodore Folger, of Washington, Chief of the Bureau of Ordnance, John Fritz, Superintendent of the company, and Russell W. Davenport were more than pleased. The target was a 10½-inch Harveyized nickel-steel plate, eight feet long and six feet wide. It weighed 18,600 pounds. An innovation was introduced in its manufacture. Ice-water was squirted against one side while being tempered. The purpose was to give the outside a hardened surface to turn away the projectiles.

The plate was firmly fastened to an armor-plate butt by twenty-four bolts screwed into thread holes at the back of the plate. Five shots from an 8-inch gun were

HARVEY ARMOR PLATE, TESTED NEAR BETHLEHEM, PA., JULY 30, 1892

10¼-inch Harveyed nickel-steel. Five shots from an 8-inch gun. Projectile, 250-pound Holtzer. Velocity, 1,700 feet per second.

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fired. The charge with each shot was eighty-one and three-quarter pounds of powder and a 250-pound Holtzer projectile. The velocity of the projectile fired from the gun was 1,700 feet a second. The first four shots were fired into the four corners of the plate. The fifth and last projectile was fired into the centre. Each projectile pierced it about three inches and then rebounded, to fly into pieces the size of a walnut.

The firing was in charge of Lieutenant J. F. Meigs, late of the United States Navy. After the test, Lieutenant Meigs made the following statement: "Comparing this test with the plates of foreign manufacture tested at Annapolis last November a year ago, and with those of domestic manufacture fired at in November last at Indian Head, there is evident a very material increase in ballistic resistance. The velocity of the 8-inch projectiles in this test was the same as their speed in the two former trials. But the five projectiles fired in all at each plate were made up in the case of the two former trials of one 8-inch, and four 6-inch projectiles, while in the present case five 8-inch projectiles were used."

Commodore Folger said: "The test showed this to be the most wonderful armor-plate ever made. Its resisting power was astounding. Though it was more severely tested than any other plate, the shots had not the slightest effect on it."

As a result of these experiments the United States Government formally adopted the Harvey process for the new armor.

The Secretary of the Navy in his report for 1893 says :

"Exhaustive experiments have conclusively demonstrated the beneficial results obtained by the application of the Harvey process and arrangements have recently been made to Harveyize such of the armor under the old contracts as was not too far advanced in manufacture to admit of the change, or as would not seriously delay the completion of the ships. In consequence of this much of the side armor of the Maine, Texas, Indiana, Oregon, and Puritan, the turret armor of the Maine, Puritan, and Monadnock, and the barbettes of the Oregon, will be Harveyed nickel steel. All the armor provided for under the new contracts will be treated by the Harvey process."

An agreement was made with the Navy Department in which the Government agreed "to bear all the expense of the experimental development of the process as applied to armor-plates."

This agreement was supplanted by another made in the following year when the Government agreed to pay a royalty for all the Harveyed armor.

Of course the success of these plates stimulated criticism from all sides of all forms and degrees. In the early history it was said that

"It was not done," that "Mr. Harvey was deceiving himself." Later it was said that "there is nothing new about it, all old steel-makers have known about it from the days of Tubal Cain."

If the process and its results were known to all old steel-makers, these same men must have also known the rewards awaiting its successful application to armor-plate manufacture.

The requirements of armor were well known; the ship-builders wanted an armor-plate with a hard surface and a tough back and free from a tendency to separate, but no one made a plate fulfilling those conditions until shown how to do it by Mr. Harvey. Moreover, it took a good many failures to teach these "old steel-makers" that unless they followed Mr. Harvey's directions and plans exactly they would not accomplish the same results.

Even in Europe all the early plates had to be supercarburized and hardened, and the furnaces designed and built under the supervision of experts sent by the Harvey Steel Company from America, as the most skilful experts failed to find their knowledge of steel processes at all adequate.

From 1892 to 1895 either Mr. Dickinson or Mr. Hayward A. Harvey, Jr., were in Europe for this purpose, and treated plates, at Sheffield, England; at Glasgow, Scotland; at St. Charmond, Montlucon, and at Rive-de-gier, France; at Dillengen, Germany; at Witkowitz, Austria, and at Terni, Italy.

Thus was repeated in Europe the experience of America; that is, all the early plates were made by Mr. Harvey or by his assistants, and everywhere the old armor-plate makers had to be instructed in the details of the new process.

New York Tribune, November 9, 1892.

AMERICAN ARMOR-PLATE.

The recent competitive trial of all-steel, nickel-steel, and compound armor-plates was the most important contest of guns against armor ever held anywhere. Other tests have since been made at the Naval Proving Ground at Annapolis, Md., and, like the one above referred to, have proved the superiority of the nickel-steel and the Harveyized-steel armor to any manufactured in any other part of the world. American Navy officers and steel manufacturers have reason to feel proud of the absolute success of this armor-plate in the severe tests made by the British Admiralty at

Portsmouth, England, last Tuesday. All the projectiles were completely destroyed, being broken into small fragments, and not a single crack was developed in the 10½-inch thick plate used. The experts admit that the test was the most important one ever made, "and may result in the adoption of the American process for making armor for British ironclads."

This process, which has been successfully applied, is a treatment for hardening the plate several inches deep, leaving the remainder in its original condition. It is intended to secure a hard face having a tough back. The object is to keep out or break up the projectile on the outside, while the tough back holds the plate together. The plate to be heated for hardening is made of mild steel containing from .10 to .35 per cent. of carbon, and after being formed into its final shape it is laid flat upon a bed of finely powdered dry clay or sand, which is deposited on the bottom of a fire-brick compartment in the heating chamber of the furnace. The upper surface of the plate is then covered with powdered carbonaceous material, tightly packed, and over it is a layer of sand covered with fire-bricks. The furnace is then lighted, and raised to a temperature sufficient to melt cast iron, and this heat is maintained for a greater or less period, according to the amount of carbonizing to be effected. About five days are said to be necessary to carbonize a plate ten and one-half inches thick. It is a most important triumph of American inventive talent, and seems destined to revolutionize modern methods of warfare.

THE HARVEY ARMOR IN EUROPE

In January, 1892, the Harvey Steel Company contracted with Mr. Edwin Marshall Fox to become their representative in Europe and present the claims of the Harvey armor-plate to the ministers of marine of the various nations, and shortly afterward Mr. Fox sailed for Europe.

His first visit was to Russia, as the Government of that country was, at the time, about to construct two new battle-ships requiring a large quantity of armor, and he sought to impress upon his Excellency Minister Tchichakof the great advantage of the Harvey plate over compound plates then employed. The Minister ordered a trial Harvey plate to be made and tested. As no armor-plant existed in Russia capable of making a plate of the thickness required by the Government, it became necessary to have the same constructed elsewhere, so Mr. Fox proceeded to France to arrange to have the plate manufactured by one

of the armor firms of that country. He found, however, much opposition, and was unable to make a contract for the manufacture of this trial plate.

He then went to England and visited the leading armor makers of that country, but they all declined to have anything to do with the new invention.

The time thus consumed in endeavoring to get a trial plate to satisfy the requirements of the Russian Government resulted in the opportunity being lost of securing a contract for armor-plate for the Russian battle-ships in question, as the Government would not wait.

Mr. Fox then endeavored to interest the British Government in the invention. He laid all the facts before the Chief Constructor of the Navy, Sir William White, who, after consideration, concluded to give the new armor-plate a trial. The Admiralty gave an order for an armor-plate to be made by the Harvey process, but stipulated that the plate must be made in England.

As all the armor manufacturers in the country positively refused to assist in any way the introduction of the new invention, Mr. Fox deter-

mined to form a company which would make armor-plates in England, and thus be independent of the existing manufacturers. To this end, as a preliminary step, he formed a syndicate of many prominent men, among whom were E. Windsor Richards, President of the Iron and Steel Institute; Admiral Fitzgeorge, son of His Royal Highness the Duke of Cambridge; Lord Sudley, Major-General Stuart Nicholson, Earl Cairnes, and Sir Norman Pringle, Bart. He also received assurances of strong financial support from bankers and others.

The position thus taken of acting independently of the armor manufacturers led to an important modification of their attitude toward the new invention, and soon the syndicate were enabled to contract with one of the firms, Messrs. Vicker's Sons & Company, for a trial plate for the British Government. They at once proceeded to erect a furnace at the works of that company in Sheffield.

The plate in question had the following dimensions: Eight feet long, six feet wide, and ten and one half inches thick. When finished it was placed for trial on the proving ship Nettle at Portsmouth harbor, and the trial

FIRST ENGLISH PLATE, TESTED NOVEMBER 1, 1892

Stanford

took place November 1, 1892. Five shots were fired at the plate, each shot weighing one hundred pounds. The striking velocity of each shot was about 1,975 foot seconds. The shot were all smashed on the surface of the plate, and the penetration in no case was more than three inches. Sir William White and the other officials present were much surprised and pleased at the result, for they had never seen anything before so remarkably effective in armor trials.

The following is an extract from a letter received from Mr. Fox at this time.

5 Waterloo Place, London, S. W.,
November 2, 1892.

To the Board of Directors, Harvey Steel Company,
New York.

Gentlemen: It is with much pleasure that I confirm my cable information about the grand success of the Admiralty trial.

The Government officials present were Captain Pearson, Commander of the Excellent, Mr. W. H. White, C. B., Director of Naval Construction, a Committee from the School of Gunnery, and one from the Ordnance Department, besides officials from Shoeburyness.

We boarded the Government tug at ten o'clock and in thirty minutes had arrived at the Nettle, which was off Whale Island, in the harbor entrance.

Everything on the Nettle was in readiness. The tar-

get had been painted and, excepting for the burn in the upper left-hand corner, looked very nice indeed.

The details of firing were as follows: Gun, 6-inch B. L. R.; distance of target from muzzle, 30 feet; projectiles, three Holtzer, two Palliser; weight of projectile, 100 pounds; powder charge, 48 pounds, E. X. E.; velocity, 1,975 foot seconds.

The plate was supported by side plates of iron and had the usual backing, which I understand to be three foot six of oak and a thin iron plate.

When all was cleared for action everyone but the gunner went below and the order to fire was given. Returning to the deck we saw, as soon as the smoke cleared away, that the plate was all right; the shell had been smashed into small fragments, the point welding by the heat of impact into the plate at a depth (apparently) of an inch or so. The indent was trifling and no sign of a crack was visible.

The second shot was substantially the same. The third and fourth Pallisers seemed to be as good as the Holtzer. They each scooped out a small circular place about one and a half inch deep and about (I judge) six inches in diameter.

After the fifth shot we all carefully examined the plate. It was simply perfect, and apparently could have stood five more shots without material injury. Not a crack was to be seen. Everybody was delighted.

On landing, Admiral Colomb, Major Geary, Albert and Thomas Vickers and myself all went to the telegraph-office each to telegraph his friends, and I suggested that we all join in one cable to you. The proposition

was received with joy. I wrote the despatch, Vickers amended it by saying "Put in that we all think it the best plate ever fired at in any country;" and I inserted the same. We all then adjoined to the Keppel's Head Hotel and in a glass of gold seal champagne I proposed the health of Hayward Augustus Harvey, a toast that was drank, I assure you, with downright enthusiasm.

Very truly yours,

(Signed) EDWIN M. FOX.

Admiral Colomb has just been in and says that he fully believes the plate would have stood five more shots. "Not only were there no cracks," he observed, "but there wasn't even the tendency to crack. It is a great—a vast triumph."

(Signed) E. M. F.

It was now evident that Mr. Harvey's invention was all that he claimed for it, and that plates made under his process were fifty per cent. better than those previously made. The armor makers, however, were not yet prepared to accept the situation, at least to the extent of paying tribute to the American inventor, for one of the firms immediately commenced to contest the validity of Mr. Harvey's patents. Mr. Fox met this difficulty by retaining Sir Richard Webster, Q. C., previously Attorney-General; Mr. Fletcher Moulton, Q. C., and

Mr. Aston, Q. C. Before the matter came to court, however, an adjustment of all the differences was arrived at, and a company formed called the Harvey Steel Company of Great Britain, Limited, with a capital of £190,000, and the various armor-making firms promptly took license therefrom.

The First Lord of the Admiralty, in his report to Parliament in March, 1894, reports as follows :

"The past year has been remarkable for the results obtained from experiments conducted with steel armor treated by the Harvey process. Armor-plates supplied by five firms have been tested by and for the Admiralty. The investigation has been most thorough and extensive, and as a result orders have been given for Harveyed steel armor for the Renown, Majestic, and Magnificent. In the course of the experiments the use of nickel as an alloy for steel for the purpose of armor-plates has been fully tested. It has been established that Harveyed plates without nickel in the steel show resistance to modern projectiles as great as any hitherto obtained where nickel was combined with steel in plates also treated by the Harvey Process. The consequence of adopting this new system will be a great saving in cost for a given defence. By means of these improvements the power of defence obtainable with certain thickness and weight of armors has been very greatly

increased, and this circumstance must considerably affect the designs of battle-ships to be laid down in the future."

Meanwhile, much opposition was being made by the firm of Schneider & Company, of Le-Creusot, France, who had a patented armor-plate of their own.

As the result of protracted negotiation a company was formed known as the société des Procédés Harvey, with a capital of 3,000,-000 francs, and licenses were granted to the St. Chamond Steel Works, the Chatillon et Commentry Company, and Marrel Frères, and a trial made for the Government of France, which proved equally successful to the English trial plate. Subsequently Messrs. Schneider took a license to manufacture Harvey plate.

Mr. Fox next formed a company for the rest of Europe, which became incorporated as the Harvey Continental Steel Company, Limited, with a capital of £120,000. Each of these companies had certain prescribed limits for the manufacture of the new invention, the English Company having the field of Great Britain, the French having the rights of France, and the Continental Company having the rights

of the rest of the world, except the United States, the rights for which remained in the Harvey Steel Company of New Jersey.

In July, 1893, Mr. Fox returned to America to submit his report and bring the first payment on account to the Harvey Company. He spent several hours with Mr. Harvey recounting the triumphs of the new armor and explaining the details of the great revolution which the invention had caused in the armor-plate industry of the world, and he predicted that the Harvey armor-plate was bound to supersede all other armor-plates in all nations. He assured Mr. Harvey that so highly was his great invention thought of in Europe by the different governments that it was not unlikely that before long he, Mr. Harvey, would receive decorations and titles for his great discovery. It was most gratifying to his friends that Mr. Harvey should have had this opportunity to have the whole scope of the enterprise in Europe thus laid before him at that time, for a month later he was dead.

The success of the armor-plate continued to grow, each additional test proving more and more emphatically the wonderful character of

the change effected by the great invention of Mr. Harvey.

By the year 1896, the Harvey armor-plate had become acknowledged throughout the world so completely that no other armor-plate was in use.

At the present time all the armor makers of the world pay tribute to some one of the different Harvey Companies for all the armor they manufacture, and the business has grown to be a very large and important one, and the armor has been adopted as the standard by all the European Governments.

Ten European, three South American, and two Asiatic nations have ships protected with Harveyed armor, England leading with twenty-two battle-ships and forty-five cruisers.

On March 15, 1894, the thirty-fifth session of the Institution of Naval Architects, Mr. Charles E. Ellis, managing director of the firm of John Brown & Co. (Limited), read a paper entitled "Recent Experiments in Armor." In this paper he makes the following statement as his conclusion :

"With the above facts before us, we are enabled to form some idea of the improvements that have recently

been effected in armor-plate manufacture, and of the relative value of the various kinds of armor.

"Without disregarding the excellent qualities of steel and nickel plates which I have alluded to earlier in this paper, I think I have shown that Harveyed armor would be a more efficient defence to the vital parts of any ship of war, whether battle-ship or cruiser, than any other type of plate. Opinions may differ as to the percentage of superiority it possesses, but I do not think that I am over-estimating its value when I place its resisting power at fifty per cent. above the steel compound plates of 1888 which I have chosen as the basis of comparison. This advantage can be used by the naval architect in one of two ways: he can either clothe with armor a greater part of his ship, or he can obtain greater resistance keeping the same thickness of armor. The new development is, therefore, of the greatest importance, and it will be a matter of satisfaction to this institution that the British Admiralty have been the first naval authority in Europe to realize the value of this new form of armor, and to apply it to their most recent designs."

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THE BATTLE-SHIP MAINE

The first vessel of the U. S. Navy to be protected by Harvey armor

THE HARVEY PROCESS

The process of "Harveyizing" has produced such marvellous results in increasing the resistance of armor-plate to the enormous penetrative strains to which it is subjected, that a word may be added as to the essential characteristics of the Harvey process and the "Harveyized" plates, and their striking features of novelty.

Armor-plates are made of masses of steel so large that ordinary methods of treatment, which could be successfully practised on smaller articles, seem manifestly to be impracticable.

Steel had for many years prior to Mr. Harvey's invention been settled upon as probably the only proper material for armor-plate, especially on account of its capacity for hardening when chilled; but rapid chilling of such large masses of steel as constitute an armor-plate was universally believed to be impossible without danger of cracking the same, or setting up fatal internal strains, if the carbon contents of

the steel were sufficiently high to produce any material hardening effect.

Armor-plates of high-carbon steel were, therefore, unknown in practice, and believed to be impossible.

Hence, many plates were made (especially by the Continental and early American manufacturers) from steel which was comparatively low in carbon, and these plates were subjected to only mild processes of chilling, such as in oil or lead.

But such plates were inadequate in hardness to break up projectiles, and were often completely perforated in use.

Many attempts to unite the characteristics of a very hard face with a softer back had been made by compounding plates of different characteristics, but these failed because of the tendency to separate at the joint, if the two parts differed from each other in composition, and the welded joint was almost always lacking in strength and liable to fracture, owing to the existence of initial strains due to uneven shrinking of the different parts.

" Cementation " had been vaguely suggested by several experimenters as a remedy for the

peculiar difficulties which were met with in armor manufacture, but no practicable details had been given by anyone prior to Mr. Harvey, and the violent chilling of such a plate had not been even proposed.

The so-called "case-hardening" of small objects had also been known for centuries as applicable to articles of small bulk, but no process of "case-hardening" seemed applicable to overcome the difficulties encountered in armor making, owing, among other things, to the thinness of the hardened skin or "case" which was commonly produced, and to the abrupt character of the transition from the harder condition of the external skin to the softer parts under the skin.

At this point in the history of the development of armor, when all expedients seemed futile to produce the ideal characteristics which had long been suggested, Mr. Harvey solved the problem by the conception and proof that the large mass of an armor-plate, if made of homogeneous low steel, could be *deeply* impregnated with carbon, upon the impact face only, by prolonged subjection of such face to the action of carbon under pressure, at a heat,

in the furnace chamber, high enough to melt cast iron, and that the result of such high and prolonged heat and persistent pressure of the carbon on one face, while the back was protected, would be to cause such a *gradually* diminishing percentage in the distribution of carbon inward, from the working face, as to obviate all difficulties previously experienced in tendencies to cracking due to the abruptness of the line of demarcation between the harder and softer parts.

The Harvey process thus, for the first time, made it possible to produce an intensely hard surface on armor, by adapting it to be "chilled" in the most energetic manner—as by spraying with cold water—without material danger of cracking the plate or its "glass-hard" face, and without producing any tendency to separate the "chill" from the soft back. The remarkable adherence of the extremely hard face of a "Harveyized" plate to the soft body and back, and the efficient yielding or cushioning effect of the back in allowing the hard face to give elastically when struck, and thus throw off and break up the projectile, is doubtless due to the characteristic of *gradually* diminish-

ing ("decremental") distribution of the carbon *behind* or *beneath* the intensely hardened surface layer, which is technically known as the "chill," and which is formed on one face only, so as to leave the back and sides of the plate free to yield.

This decremental distribution of the carbon which occurs both *in* and *under* the "chill," is produced by the high and prolonged heat which results in deep carburization, and it was this practice which was boldly suggested and successfully practised by Mr. Harvey, contrary to the belief in its practicability by most, if not all, experienced steel workers, who naturally supposed that such a treatment would fatally endanger plates of such magnitude.

APPENDIX A

LIST OF WAR-SHIPS WITH HARVEY ARMOR

GREAT BRITAIN.

Battle-ships :

Renown,	Jupiter,	Formidable,
Majestic,	Mars,	Implacable,
Magnificent,	Canopus,	Irresistible,
Prince George,	Glory,	Vengeance,
Victorious,	Goliath,	London,
Illustrious,	Albion,	Venerable,
Cæsar,	Ocean,	Bulwark.
Hannibal,		

Cruisers, 1st Class :

Powerful,	Spartiate,	*Aboukir,
Terrible,	Diadem,	*Cressy,
Andromeda,	Ariadne,	*Hogue,
Europa,	Argonaut,	*Lutley, and
Niobe,	Amphitrite,	*four others.

Cruisers, 2d Class :

Talbot,	Isis,	Vindictive,
Eclipse,	Juno,	Arrogant,
Minerva,	Diana,	Hyacinth,

*Armored Cruisers.

Cruisers, 2d class—Continued :

Dido,	Gladiator,	Highflyer,
Doris,	Furious,	Hermes.
Venus,		

Cruisers, 3d Class :

Pelorus,	Pandora,	Prometheus,
Pomone,	Pioneer,	Pegasus,
Proserpine,	Pactolus,	Pyramus.
Psyche,	Perseus,	

ARGENTINE REPUBLIC.

Armored Cruisers :

Garibaldi, San Martino.

Cruiser :

Buenos Ayres.

AUSTRIA-HUNGARY.

Coast Defence Ships :

Budapest, Monarch, Wien.

Armored Cruiser :

"D."

BRAZIL.

Coast Defence Ships :

Marshal Deodoro, Marshal Floriano.

Turret River Boats :

Maranhao, Pernambuco.

APPENDIX A

CHILI.

Armored Cruisers :

Almirante O'Higgins, Esmeralda.

Cruiser :

Ministro Tentino

CHINA.

Cruiser :

Hai-Chi.

DENMARK.

Coast Defence Ships :

Skjold, Herluf Tralle.

FRANCE.

Battle-ships :

Massena, Henry IV., Jena,
Saint Louis, Gaulois, Jeanne d'Arc.
Bouvet,

Cruiser, 1st Class :

D'Entrecasteaux.

GERMANY.

Coast Defence Ships :

Aegir, Hargen, Hildebrand,
Frithjof, Heindall, Odin.

Armored Cruiser :

Fürst Bismarck.

Cruisers, 1st Class :

Kaiser Friedrich III., Kaiser Wilhelm II.
Konig Wilhelm,

Cruisers, 2d Class :

Freya, Hertha, Vineta.
Hansa, Victoria Luise,

ITALY.

Battle-ships :

Ammiraglio di St. Bon, Emanuele Filiberto.

Armored Cruisers :

Giuseppe Garibaldi, Varesse,
Vetor Pisani, Carlo Alberto.

JAPAN.

Battle-ships :

Asahi, Yashima, Fuji.
Shikishima, and one more,

Armored Cruisers :

Asama, Kasaji,
Takasage, Tokiha, and one more.

NETHERLANDS.

Coast Defence Ships :

Evertsen, Kortenaer, Plet-Hein.

NORWAY.

Coast Defence Ships :

Harold Haarfagre, Torkenskjold.

APPENDIX A

RUSSIA.

Battle-ships :

Oslabya, Peresviet, Sevastopol.

Cruisers :

Poltava, Petro Pavloosk, Rostislav.

SPAIN.

Armored Cruisers :

Cristobal Colon, Pedro d'Aragon.

UNITED STATES OF AMERICA.

First-class Battle-ships :

Indiana,	Massachusetts,	Alabama,
Iowa,	Kearsarge,	Illinois,
Oregon,	Kentucky,	Wisconsin.

Second-class Battle-ships :

Maine, Texas.

Armored Cruiser :

Brooklyn.

Protected Cruiser :

Olympia.

Double Turreted Monitors :

Monadnock, Puritan.

APPENDIX B

LIST OF AMERICAN PATENTS ISSUED TO HAYWARD A. HARVEY

This list is not complete prior to 1860.

No. of Patent.	Article.	Date.
26492	Railroad chair	Dec. 20, 1859
42474	Screw-blank feeder	April 26, 1864
42475	Wood screw	April 26, 1864
42476	Screw-blank feeder	April 26, 1864
42477	Screw-blank feeder	April 26, 1864
42766	Making wood screws (threader)	May 17, 1864
42767	Making wood screws (shaver)	May 17, 1864
42768	Making wood screws (nicker)	May 17, 1864
44090	Heading bolt and screw-blanks	Sept. 6, 1864
44723	Shaving screw-blank heads	Oct. 18, 1864
44724	File	Oct. 18, 1864
47548	Making wood screws	May 2, 1865
47549	Screw-blank feeder	May 2, 1865
51179	Screw-threading machine	Nov. 28, 1865
63385	Wire staple	April 2, 1867
64976	Sash weight	May 21, 1867
66331	Nail	July 2, 1867
66585	Wood screw	July 9, 1867
71166	Screw nail	Nov. 19, 1867

APPENDIX B

No. of Patent.	Article.	Date.
72633	Wood screw	Dec. 24, 1867
121050	Improvement in brushes	Nov. 21, 1871
154864	Bolts and nuts	Sept. 8, 1874
154865	Mode in forming nicked heads of screws	Sept. 8, 1874
175087	Machines for making corrugated-legged staples	Mar. 21, 1876
197466	Bolt and nut	Nov. 27, 1877
197467	Nut and bolt lock	June 4, 1877
197933	Wood screw	Dec. 11, 1877
204036	Bolts and nuts	May 21, 1878
221729	Screw nail	Nov. 18, 1879
223730	Machine for rolling threads of screws or bolts	Jan. 20, 1880
224591	Lock nut	Feb. 17, 1880
240702	Machine for corrugating nails	April 26, 1881
248163	Feeding mechanism for machines for rolling screw-threads	Oct. 11, 1881
248165	Machine for rolling screw-threads	Oct. 11, 1881
248166	Apparatus for feeding blanks to machines for rolling screw-threads	Oct. 11, 1881
248167	Process for threading screws	Oct. 11, 1881
248168	Manufacturing screws and screw-bolts	Oct. 11, 1881
248169	Manufacture of screws	Oct. 11, 1881
250728	Tap and die	Dec. 13, 1881
251874	Machine for rolling threads of screws or bolts	Jan. 3, 1882
251875	Machine for tapping nuts	Jan. 3, 1882

APPENDIX B

No. of Patent.	Article.	Date.
272877	Automatic nut-tapping machine	Feb. 27, 1883
273731	Nut and bolt	Mar. 13, 1883
274492	Tap for cutting spiral wedge nuts	Mar. 27, 1883
284633	Machine for rolling threads of wood screws	Sept. 11, 1883
288798	Screw	Nov. 20. 1883
319247	Rolled wood screw	June 2, 1885
321214	Gimlet-pointed rolled wood screw	June 30, 1885
327261	Screw tap	Sept. 29, 1885
327263	Screw tap	Sept. 29, 1885
328217	Machine for rolling screw-threads	Oct. 13, 1885
329737	Screw swaging machine	Nov. 3, 1885
329738	Spring washer	Nov. 3, 1885
329900	Method of making rolled wood screws	Nov. 10, 1885
340308	Nut lock	April 20, 1886
357001	Machine for rolling screws	Feb. 1, 1887
357002	Machine for rolling screws	Feb. 1, 1887
376194	Process of treating low steel	Jan. 10, 1888
377452	Wire screw nail	Feb. 7, 1888
377453	Rolled headed wood screw and process of making the same	Feb. 7, 1888
379393	Machine for making washers	Mar. 13, 1888
383949	Screw swaging machine	June 5, 1888
385621	Wide-range yielding washer	July 3, 1888
395899	Railroad spike	Jan. 8, 1889
420557	Machine for making spiral washers	Feb. 4, 1890
440631	Resilient spiral washer	Nov. 18, 1890
456723	Rolled spike	July 28, 1891

APPENDIX B

No. of Patent.	Article.	Date.
460268	Decrementally hardened armor-plate	Sept. 29, 1891
460269	Gun	Sept. 29, 1891
464301	Resilient spiral washer and making of the same	Dec. 1, 1891
498390	Composition for supercarburizing steel	May 30, 1893
506689	Manufacture of steel rails for railroads	Oct. 17, 1893

American Patents Issued to Mr. Harvey in Conjunction with other Inventors.

128251	Machinery for making brushes, with C. D. Rogers, and M. P. Wilkins	June 25, 1872
306132	Machine for rolling screw-threads, with C. S. Clark	Oct. 7, 1884
314935	Screw-pointing machine, with C. S. Clark	Mar. 31, 1885
314936	Machine for nicking screw-blanks, with C. S. Clark	Mar. 31, 1885
327262	Steel die, with C. S. Clark	Sept. 29, 1885
348967	Multiple screw-shaving machine, with C. S. Clark	Sept. 14, 1886

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